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Improving the Accuracy of the SeaUV Algorithms in Dark Marine Waters

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LONG-TERM GOALS

Our long-term objective is to develop a robust set of algorithms for the global ocean to provide accurate surface UV attenuation and CDOM retrieval from remotely sensed ocean color for use in optical, photochemical, and photobiological investigation.

OBJECTIVES

The central objective of this project is to generate new, high quality optical data sets for a variety of darker coastal systems to be used in evaluating SeaUV algorithms and retraining them for accurate use in the highly variable optical conditions typical of the nearshore environment.

APPROACH

Previous ONR funding in our lab produced two improved and ready-to-use algorithms (SeaUV and $\mathrm{SeaUV_C}$) detailed in Fichot (2004) and Fichot et al. (2008). These algorithms are used for estimating *Kd*(320-490) and $a_g(320)$ from measurements of spectrally resolved remote sensing reflectance, $Rrs(\lambda)$. Our general approach for this project is to collect new in situ optical data sets for near coast and inshore dark waters, apply the SeaUV algorithms to this new data set for evaluation of current predictive capability, and incorporate these new data into the training data set for evaluation of improved predictive capability using new 'dark trained' algorithms. The final product will be a single model that will predict Kd(UV) and $a_g(\lambda)$ from ocean color in optical domains ranging from the clear open ocean to the dark waters found in close proximity to the coast. We will then apply these trained algorithms to independent data sets where possible for validation.

Approach to Fieldwork: We collect simultaneous *in situ* measurements of Lu(λ), $Kd(\lambda)$ and $a_g(\lambda)$ in the dark waters found near the coast, focusing efforts around the UGA Marine Institute (UGMI) on Sapelo Island, GA (see Figure 2). Past ONR funding has provided the Satlantic® instruments to collect high quality UV-Vis data for use in the SeaUV algorithms: a Satlantic® MicroSAS ocean color buoy (2 sensors for below-surface multispectral visible upwelling radiance: wavebands = 412, 443, 490, 510, 555, 670 and 683nm) is deployed adjacent and coincident with a Satlantic® Micropro free fall profiling radiometer (2 sensors for below-surface multispectral UV-Vis downwelling irradiance: wavebands = 305, 325, 340 380, 412, 443, 490, 555nm) and a reference radiometer (2 sensors for above-surface

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multispectral UV-Vis downwelling irradiance: wavebands = 305, 325, 340 380, 412, 443, 490, 510, 555, 670 and 683nm). Water samples for spectrophotometric determination of $a_g(\lambda)$ are collected simultaneously with all survey optical data.

We seek out opportunities to deploy our Satlantic systems in as many inshore and near-coastal waters as possible using “cruises of opportunity” in order to supplement the southeastern US data set, thus adding potentially different optical domains to the training set. This year an opportunity for multiple seasonal cruises in the Gulf of Mexico has allowed expansion of our optical data set to nearshore stations along onshore-offshore transects in the gulf (see Figure 1).

Approach to Data Analysis: The new in situ Lu(λ) data collected in dark coastal waters is processed with the SeaUV and SeaUVc algorithms to generate modeled $Kd(\lambda)$ and $a_g(\lambda)$ estimates for the region. The measured *in situ* $Kd(\lambda)$ and $a_g(\lambda)$ data is then compared to the model with statistical analysis following that of Fichot et al. (2008). The new ‘dark water’ optical data sets are then added to the SeaUV training set, the model is retrained, and new estimates are re-evaluated for performance in all optical domains. As we accumulate sufficient dark water *in situ* UV optical data to make the approach statistically valid, we evaluate the use of data subsets to train type-specific versions of SeaUVc. For example, we are examining the effectiveness of constraining the training set to include only spectral data with Lu(412) values from highly absorbing water and exploring the development of algorithms specific for use in near shore systems. As new data, both from different seasons (and terrestrial flow patterns) and from different locations are obtained, we will explore how these new sets effect both specific and overall performance of the SeaUV algorithms. A continued statistical examination of both the “blue water” and the “dark water” accuracy is repeatedly performed as the training set is seeded with more dark water data. The result is a more robust optical model that uses ocean color to estimate UV radiation fields in the surface ocean for use in photochemical and photobiological process models. This translates to better predictive capability of CDOM dynamics in nearshore waters.

Approach to Validation and Prediction: This involves mining existing optical databases and seeking out other sources of optical data sets (unpublished with collaboration) for ‘dark’ water to provide an independent test of SeaUV performance and future incorporation into the SeaUV training set.

WORK COMPLETED

- Miller and Fichot continued work on publications resulting from ONR funding. A paper using the SeaUV/SeaUVc model to calculate global depth resolved CO photochemistry has been resubmitted to Remote Sensing Environment (Fichot & Miller, 2009) after acceptance with minor revisions.
- Miller presented a poster at the ASLO Aquatic Sciences Meeting in Nice titled “Training the SeaUV/SeaUVc algorithms for improved inshore estimates of UV optics and photochemical and photobiological rate calculations” that will form the basis of a publication.
- We staged for and participated in three cruises to the northern Gulf of Mexico, obtaining data sets from 50 new optical stations for use in testing and training the SeaUV/SeaUVc model.
- We obtained new optical data for 15 stations located around Sapelo Island, GA and began further evaluation of the SeaUV/SeaUVc in these dark waters.
- We continued design of new configurations of optical gear with Satlantic.

- We continued training of new graduate students in the field setup and operation of our Satlantic gear and the MatLab programming required to analyze data and generate useable optical relationships.
- We continued to refine, comment, and generally detail the steps in using the SeaUV algorithms and related programs to increase usability by others following Fichot's departure from UGA.

RESULTS

Our main results for this year have been to add significantly to our field data set with surveys of DOC, CDOM, UV attenuation and water-leaving radiance. We did this by sampling the dark waters surrounding Sapelo Island, GA, working in conjunction with the GCE-LTER (Georgia Coastal Ecosystem – Long Term Ecological Research) program, and a concentrated sampling effort in the northern Gulf of Mexico, working in conjunction with an NSF funded seasonal study of pCO2. Figure 1 shows sampling sites for the GOM and Figure 2 shows sampling sites around Sapelo Island.

This year represented a renewed emphasis on fieldwork and data gathering. The results from this effort are still in the processing stage. Miller's research group, while currently without a technician, has grown from 1 to 4 graduate students since the last ONR report (one supported by ONR). The 50 optical stations occupied in the Gulf of Mexico served as an excellent training experience for 2 new graduate students. Cedric Fichot, Miller's former technician, participated in the cruises and related specific details of setup, operation, data communication, instrument testing, etc. Significant strides in training the entire group in field deployment of optical instruments have been made. The SeaUV/SeaUVc Matlab algorithms are available to the student group and all are learning the specifics of optical data analysis.

All data have been collected, correlated, and QA/QC analysis is underway. All optical profiles from the GOM have been examined and new in-house MatLab code has been written to add the choice for calculation of Kd over a discrete water depth interval (rather than for one optical depth) to accommodate the dark freshwater lenses found around the outflow of the Mississippi River. As of right now, a full statistical evaluation of the performance of the SeaUV/SeaUVc model with these new data is not yet complete. Preliminary indications are that the improvement seen last year with the addition of a limited number of 'dark' optical stations will be confirmed with the increased statistical robustness gained by added data sets. The training result for adding the new 'dark water' data to the SeaUV/SeaUVc model should result in increased accuracy for coastal waters. By expanding our survey to the northern GOM, we will increase the confidence for extrapolation of the 'dark water trained' SeaUV/SeaUVc model to other nearshore waters. Continued addition of new data in the coming year by re-sampling around Sapelo island, one more Gulf of Mexico cruise, and by day trips to new coastal areas with differing optical complexity will be build confidence in application of the model.

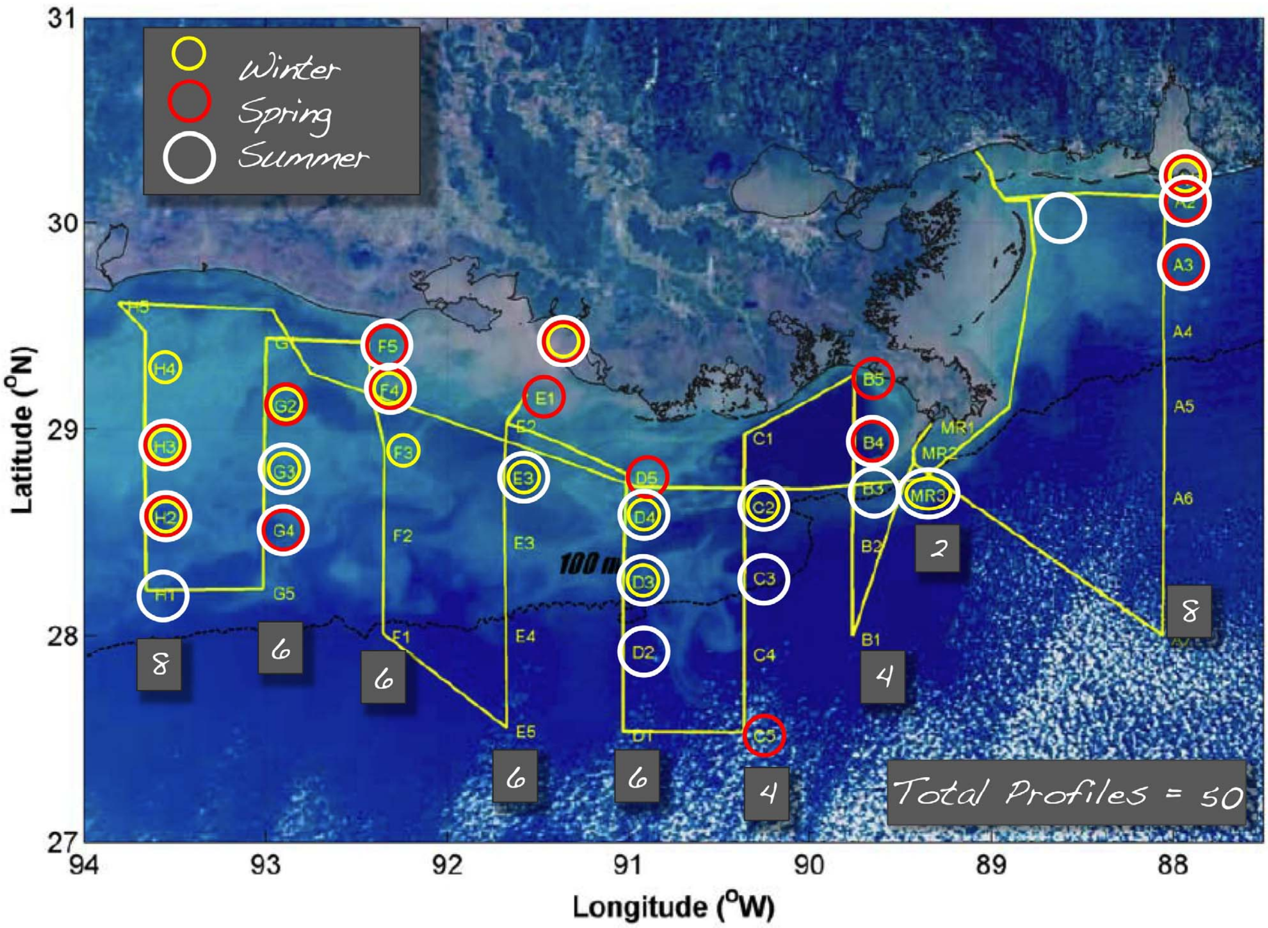

Figure 1. Sampling stations in the northern Gulf of Mexico. [remote sensing, real color satellite image of the coasts of Alabama, Mississippi, and Louisiana with adjacent coastal waters to just beyond the 100 meter isobath marked with a dotted line; a yellow ship-track line consisting of 8 onshore – offshore transects stretching from the mouth of Mobile bay to western Louisiana is overlain with 47 stations marked using alphanumeric notation; stations sampled for optics are noted with concentric colored circles around the station id, yellow = winter cruise, red = spring cruise, white = summer cruise; the 50 optical sampling efforts over the three cruises are predominantly located nearer to shore with only 3 outside the 100 meter isobath]

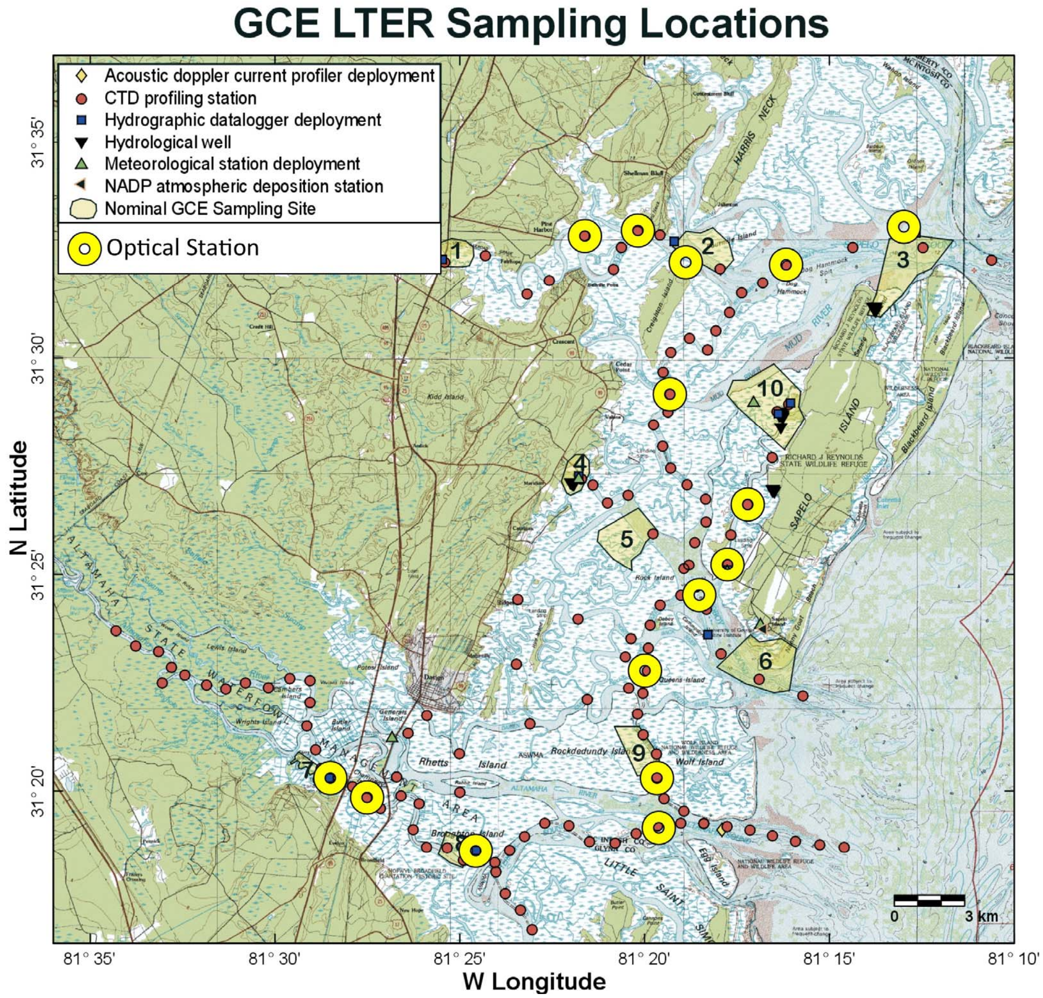

Figure 2. Sampling sites around Sapelo Island, GA [A navigational map of the Sapelo Island and vicinity with sampling sites used by the Georgia Coastal Ecosystem – Long Term Ecological Research project located; hundreds of red circles strung from the mouth of the Altamaha River, running behind Sapelo Island through the Intercoastal Waterway to the upper reaches of Sapelo Sound north of the island = GCE-LTER CTD stations, 15 yellow circles distributed more sparsely over this same area = our optical sampling sites; all optical sites are in tidal creeks and sounds.]

IMPACT / APPLICATIONS

The SeaUV/SeaUVc model has proved to significantly improve our ability to estimate UV optical properties and CDOM dynamics in the ocean and is applicable to all marine environments including both optically shallow and deep situations, areas of high productivity and particle loads, open ocean, coastal and estuarine waters. New work on dark, coastal waters will improve this performance to a level that detailed variability of dynamic inshore areas can be better observed. Understanding of the variability in CDOM will produce better models for photochemical distributions. Better quantification of CDOM will allow better corrections for CDOM in chlorophyll algorithms and characterization of the UV light field in the ocean. Associated algorithms developed for use with SeaUV that account for cloud affects on modeling UV scalar irradiance in the ocean will prove useful to all fields studying the biogeochemical role of UV in the ocean.

RELATED PROJECTS

This ONR project to refine and apply SeaUV/SeaUVc to the evaluation of UV optics and CDOM dynamics in dark waters will benefit from collaboration with a funded NASA project (Miller, PI) to use these same models to examine photochemical carbon cycling in the south Atlantic bight off the coast of the S.E. United States. A newly funded Georgia Sea Grant (NOAA) project (Miller, PI) to examine relations between ocean color and DOC in dark water for carbon export models will also be synergistic with this project. An NSF funded project to examine photochemistry in the northern Gulf of Mexico (Benner, U. South Carolina, PI) has provided access to cruise opportunities with good prospects for optical sampling.

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PUBLICATIONS

Fichot C. G., and W. L. Miller (2009) Quantifying marine photochemical fluxes using remote sensing: a monthly, global, depth-resolved climatology of carbon monoxide (CO) photoproduction. Remote Sensing of Environment. [accepted with minor revision, refereed]